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EDITORIAL

A paradigm shift in the diagnosis & management of dentofacial deformities

For many years the diagnosis of dentofacial deformities and the prediction planning of the surgical correction were limited to two dimensional (2D) radiographs and photographs. There are many limitations associated with this approach which include geometrical distortion and superimposition in 2D images, evaluation and prediction planning are limited to the patients' profile, facial asymmetries are not fully analysed and 3D soft tissue changes following orthognathic surgery are not considered.

Over the last few years there has been a significant paradigm shift in our clinical approach towards the management of dentofacial deformities (Swennen et al., 2009). The ultimate goal of orthognathic surgery is to improve the harmony of soft tissue appearance which is usually the patients' main concern. Improving labial seal, naso-labial configuration and chin prominence are amongst the main objectives for orthognathic surgery. Improving medio-lateral, vertical and antero-posterior asymmetries of facial morphology can be readily achieved with standard orthognathic procedures. The morphology of the vermillion border of both upper and lower lips is altered significantly with orthognathic surgery. Therefore, the magnitude and direction of movement of the osteotomy segmented should be planned to archive the required alterations in the oro-facial appearance. This would not be achieved unless the position and the inclination of the teeth are pre-planned to allow the desired movements of the osteotomy segments (Fig. 1). Therefore, it is a necessity for the majority of cases to undergo presurgical orthodontic treatment to decompensate and reveal the true extent of the underlying deformities in preparation for orthognathic surgery. The team approach between the orthodontist, surgeons and technologist is essential to plan the cases appropriately and archive the best possible results following orthognathic surgery (Fig. 1).

The need for comprehensive and full analysis of dentofacial morphology has inspired clinicians to adopt 3D imaging modalities to capture and analyse facial soft tissue morphology, the shape of the jaw bones as well as the dental occlusion (Benington et al., 2010, Fig. 2). Three-dimensional imaging techniques have attempted to overcome the shortcomings of conventional two-dimensional methods. These techniques have included: morphanalysis, laser scanning, 3D computerised tomography scanning, 3D ultrasonography, Moiré topography and contour photography.

1. 3D soft tissue facial capture

Stereophotogrammetry is the most common method used for the capture of facial morphology. It is a vision-based non-contact 3D imaging method which has been applied for clinical assessment of facial morphology (Hajeer et al., 2002). The method is based on facial imaging using two or more cameras (Fig. 3), configured as a stereo-pair, to generate the 3D configuration of the face by triangulation. The capture time is 1 ms and the method does not expose the patients to any harmful radiation. It does produce a 3D photorealistic image of the face which can be viewed and measured on standard computer screen. This allows the clinician to conduct a comprehensive analysis of the face, identify areas of dysmorphology and quantify facial asymmetries. Software packages are now available for the 3D analysis of facial configurations (Fig. 4). The produced images could be utilised for longitudinal analysis of shape change and monitor facial growth changes (Kambay et al., 2002).

2. 3D skull capture

The multislice and spiral CT scanners have been used routinely for imaging facial bones; the method has several disadvantages including poor resolution of the soft tissue of the face and the exposure of patients to excessive radiation. To overcome these limitations, cone-beam computerised tomography (CBCT) was introduced (Scarfe and Farman, 2008). The method is based on the use of a cone-shaped X-ray beam directed at 2D detectors which results in an image being acquired in a volumetric manner. CBCT technology provides high image accuracy with less scanning time. It produces a more focused beam and less radiation scatter which increases the X-ray utilisation and reduces the radiation dose significantly. Therefore, it is now used routinely

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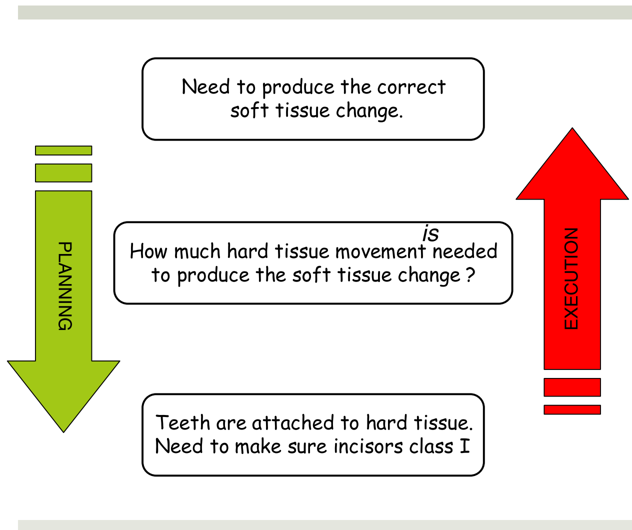

Figure 1 A diagram illustrating the mechanism of planning and executing the surgical correction of dentofacial deformities.

for orthognathic surgery planning and prediction (Fig. 5). CBCT is not only used for analysis and prediction planning, it does guide the surgical procedure and provide the surgeons with invaluable information regarding the course and the position of the inferior dental nerve, shape and anatomy of the condyles, morphology of the jaw bones and areas of skeletal asymmetry.

3. 3D Capture of dentition

It is not possible to achieve an accurate representation of the occlusal surfaces of the teeth using CBCT. When imaging patients, using CBCT, any intra-oral metallic objects (e.g. restorations, implants, orthodontic appliances) create streak

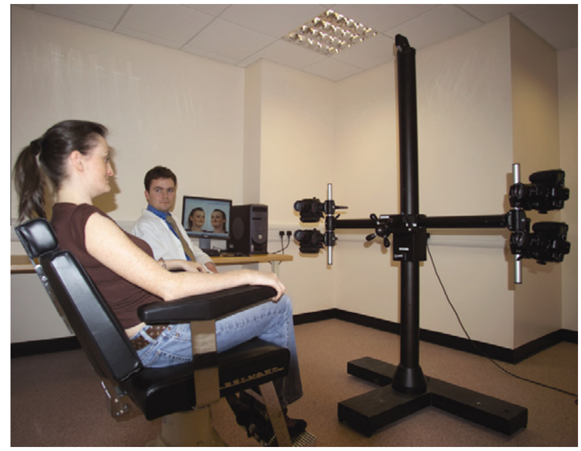

Figure 3 3D capture of the face using two stereo pairs of digital cameras.

artefacts (Park et al., 2007). These artefacts can obliterate the occlusal surfaces of the 3D images of teeth, rendering the virtual model unusable. This is a major obstacle for occlusal registration and the fabrication of orthognathic wafers to guide the surgical correction of dentofacial deformities. Several methods have been developed in an attempt to remove the streak artefacts (Nkenke et al., 2004; Sohmura et al., 2005), ranging from specialised software, which is inaccurate to extra-oral registration techniques. The problem with the latter is the device distorts the soft tissue around the area of the mouth and lips. To replace the inaccurate dentition on the 3D image, the dental cast is captured using a Laser scanner (Fig. 6), the developed image is superimposed on the 3D model of the skull using an intra-oral radiolucent device that locates markers for accurate superimposition of the dental cast model on the 3D skull image (Fig. 6).

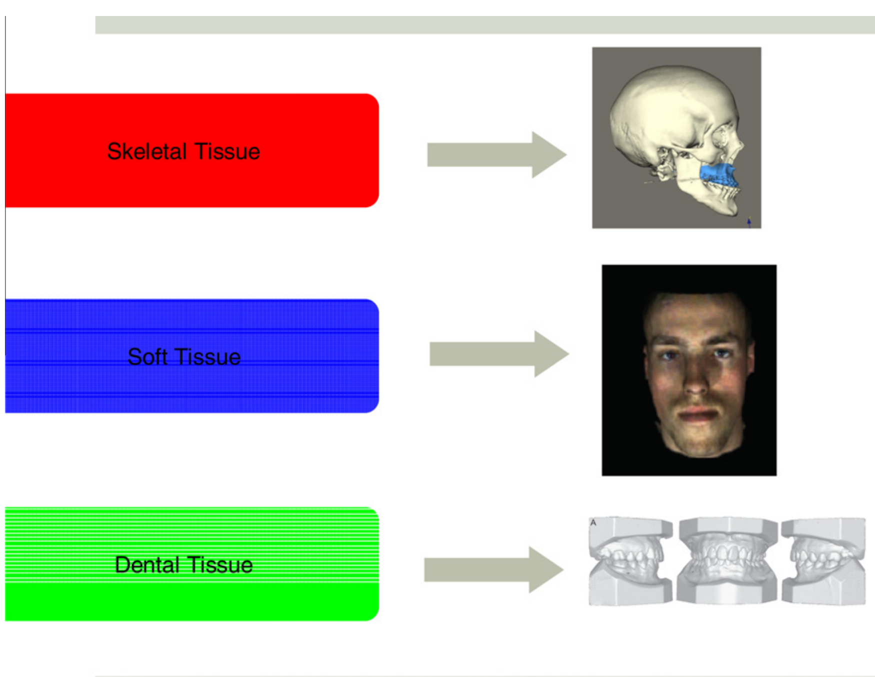

Figure 2 A diagram illustrating the 3D images of the face, skull and dentition.

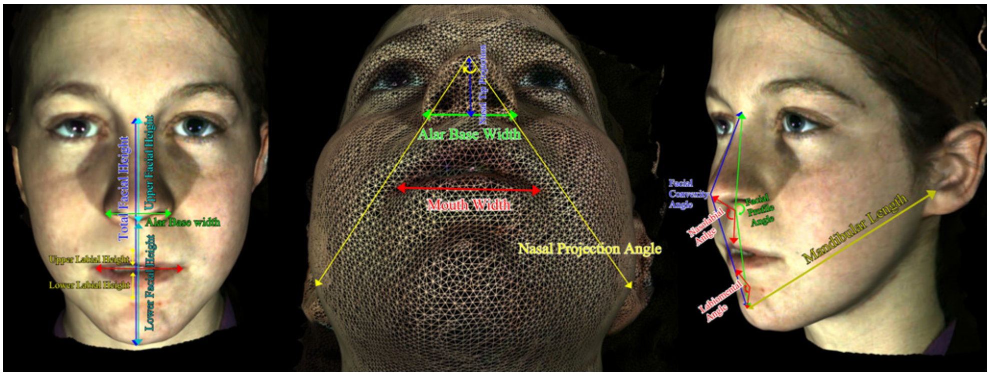

Figure 4 Analysis of 3D soft tissue morphology of the face.

Figure 5 3D capture of the skull using cone beam CT scan machine.

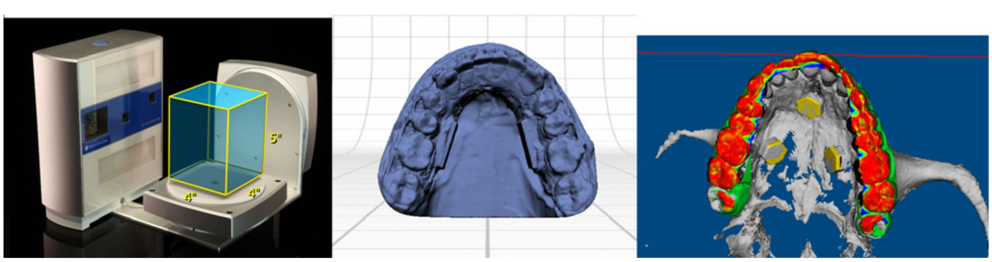

Figure 6 Laser scanning of the dental cast to produce 3D digital model which is superimposed on the 3D SBCT (this illustration is part of Mr. Neil Nairn's research project.).

4. Building the virtual face

Various software packages are available to build the virtual 3D image of the face and allow the superimposition of the photo-realistic image of the soft tissue to be superimposed on the soft tissue of the CBCT, and with accurate replacement of the distorted dentition the clinician would have, for the first time, a virtual model of the face, skull, and dentition (Fig. 7) ready for analysis and surgical planning (Gateno et al., 2003; Khambay et al., 2008).

5. Prediction planning

Computerised 3D virtual planning for orthognathic surgery has recently been introduced. The technique depends on accurate relationship of the three structures, soft tissue, bone, teeth

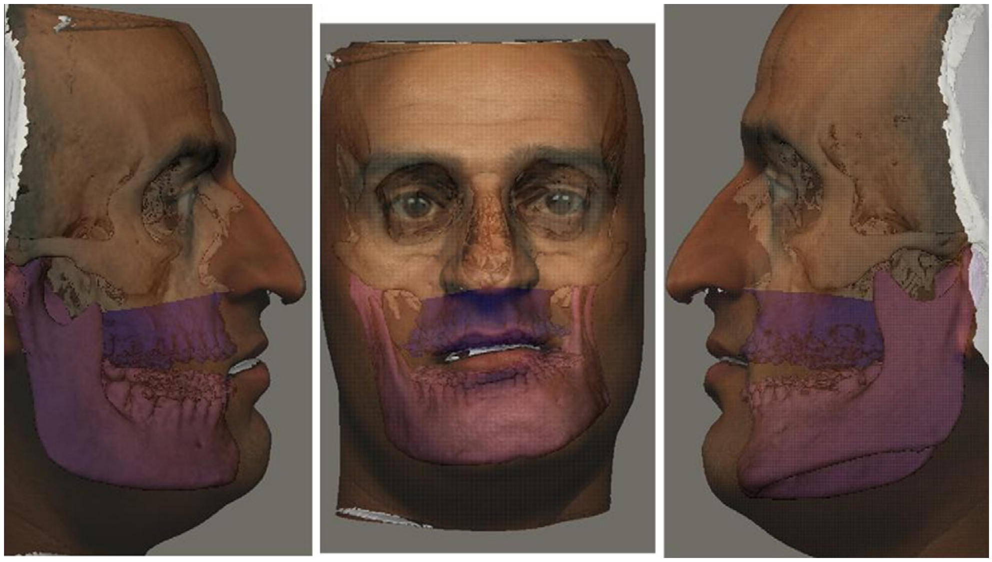

Figure 7 Virtual 3D model of the face, skull and dentition.

Figure 8 From left side, 3D preoperative image, actual 3D changes, 3D prediction planning.

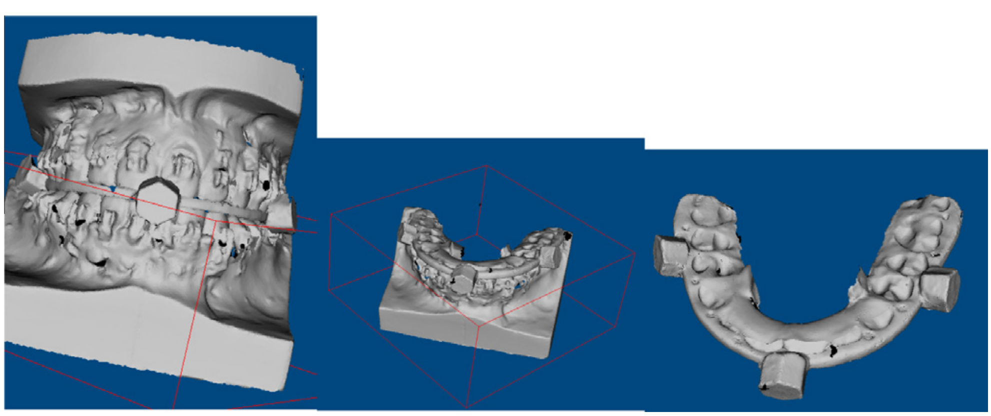

Figure 9 Fabrication of a digital wafer to guide per-operative movements of bone segments (this illustration is part of Mr. Abedalrahman Shqaidef's research project).

to each other. Several software packages are available for 3D prediction of soft tissue changes in response to orthognathic surgery (Fig. 8). Direct fabrication of a digital wafer on the 3D digital dental surfaces can be readily achieved (Fig. 9). This can be converted into a physical one to guide surgical movements of bone segment. The method has obvious potential benefits however it requires sophisticated software packages, expensive hardware and advanced expertise in image manipulation which might not readily available in some oral and maxillofacial surgery units.

In summary, in the last few years the prediction planning of the surgical correction of dento-facial deformities has improved markedly due to the utilisation of the existing facilities for 3D facial imaging and scanning of dental models. The reported advances promise an improved quality of the service delivered to orthognathic patients and a more accurate prediction of the surgical outcomes which is valuable for both patients and surgeons.

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